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USER BENEFITS AND FUNDING STRATEGIES EXECUTIVE SUMMARY

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ABSTRACT

This report describes a three-step, systematic method for selecting relevant and highly beneficial payloads for the Interim Upper Stage (IUS) that will be used with the Space Shuttle until the Space Tug becomes available. Viable cost-sharing strategies which would maximize the number of IUS payloads and the benefits obtainable under a limited NASA budget were also determined.

To accomplish the first of these objectives, SRI established criteria for justifying candidate IUS experiments/instruments. The three justification criteria were (1) relevance to accepted objectives, (2) benefit sufficiency, and (3) non-duplication of purpose. Using these criteria, SRI conducted an illustrative analysis to justify experiments/instruments and to identify potential sponsors for the justified items. The second step was to order the justified experiments/instruments in terms of importance. The criteria determined for this step were: (1) level of benefit, (2) number of application areas benefited, (3) importance of areas benefited, (4) criticality of experiments, (5) timeliness, and (6) special criteria (such as legislative action, national prestige, and previous commitments). Candidate experiments were ranked according to these criteria.

In the third step, SRI established criteria for payload selection by determining a payload importance function expressed in terms of partial importance factors for: (1) technical compatibility, (2) experiment importance, (3) experiment completeness, (4) sponsorship, (5) time phasing of costs, (6) immediacy, (7) spacecraft utility, and (8) non-duplication. SRI then performed example payload selections.

In evaluating various cost-sharing strategies, SRI assessed long-run marginal cost, short-run marginal cost, average (full) cost, two-part pricing, and value of service strategies. Each strategy was evaluated against five criteria: (1) efficiency, (2) equity, (3) sponsor's ability to pay, (4) recovery of costs, and (5) administrative ease. While particular advantages were found for using certain strategies in specific user categories, SRI determined that a flexible cost and pricing system would be preferred.

The analysis performed in the study with the methodology developed was constrained to consideration of payloads made up of experiments/instruments previously defined.

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ABBREVIATIONS

CO_2	carbon dioxide
COMMUN	Communications
EM	electromagnetic
EXP	experiment
GE	General Electric Company
GSFC	Goddard Space Flight Center
IUS	Interim Upper Stage
m, M	meter
NASA	National Aeronautics and Space Administration
PADS	Precision Attitude Determination System
PATTI	Precise and Accurate Time and Time Interval Experiment
R&D	Research and Development
RFI	radio frequency interference
SRI	Stanford Research Institute
STS	Space Transportation System

I INTRODUCTION

The United States has attained a large measure of maturity in its space programs over the past few years as evidenced by the decision to proceed with the development of the Space Transportation System (STS), which provides economical and practical means of orbiting a much larger number of payloads than previously possible. Another significant indication of this maturity is the fact that NASA is not content to define future programs by merely determining what can be done but, rather, what should be done. The Hearth Committee* has addressed this latter point at the direction of the Administrator of the National Aeronautics and Space Administration (NASA), James C. Fletcher. The findings of that Committee were consistent with the philosophy expressed in the following paragraph.

It is now evident that the basic attitudes and priorities in this country may not permit large amounts of money to be spent for space spectaculars or space endeavors for purely scientific purposes. In order to obtain support, programs must be structured to improve or maintain the qualities of life, although some purely scientific endeavors should be included. The space endeavors should be selected considering the present needs as well as long-term future needs and requirements. It is now recognized that NASA, knowing what can be done in space, must continue to actively seek partnerships with the various portions of the Federal and State Governments and the private sector that represent and minister to the various needs of man and attempt to work with these organizations to develop space efforts that can favorably impact the quality of life.

If this philosophy is adopted, as apparently is being done within NASA, then NASA will be structuring many of its programs to be responsive to, and supportive of, the needs and goals of other organizations. This

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* This is the name usually given to the Study Group for NASA's "Outlook for Space" study. Mr. Donald P. Hearth was named Study Director.

action would have a particular impact on the missions to be flown by the STS since, in the period between 1980 and 2000, this system will be used to orbit most of the payloads flown by NASA.

The Interim Upper Stage (IUS) will be used in conjunction with the Shuttle until the Space Tug becomes available in the middle 1980's. The IUS payloads are, therefore, flown early in the STS era and are among those that will be evaluated by potential users of the STS in their deliberations of whether to participate later in the program. It is important that these payloads be selected to encourage such participation. In the light of the Hearth Committee findings, this specifically means that the IUS payloads should be relevant and highly beneficial to quality of life or scientific needs. The primary objective of the Stanford Research Institute (SRI) study summarized in this report is to develop a systematic method whereby IUS payloads can be properly selected. Another objective is to determine viable cost-sharing strategies for the justified payloads in order to maximize the number of IUS payloads (and therefore, the benefits) supportable under a limited NASA budget.

To meet the stated study objectives, SRI initiated a NASA-funded study on May 1, 1975 with a three-month period of technical performance and a six-month overall duration. The following tasks were defined to accomplish the desired goals:

(1) Task 1, Justification of IUS Experiments/Instruments (Benefit Analysis)

(2) Task 2, Selection Among Justified Experiments (Importance Ranking)

(3) Task 3, Selection of Payloads

(4) Task 4, Determination of Funding and Cost-Sharing Approaches.

The analysis in the study was constrained to consideration of the IUS payloads already identified by General Electric (GE) Company and Fairchild Space and Electronics Company in their current studies sponsored by Goddard Space Flight Center (GSFC) to:

(1) Identify multi-discipline applications payloads for the 1980's that require the Shuttle-IUS geosynchronous orbiting capability;

(2) Develop concepts for such payloads, treating the Shuttle-IUS combination as a means of providing a test-bed for quick and economical experimentation in space; and

(3) Identify the technolology needed for the implementation of such payloads and concepts.

In each task, the method developed was tested by applying it in case studies. The time and funding constraints limited the research effort primarily to the development of methods and the illustration of the approach using readily available cost and benefit data from existing studies.

The following pages present a short summary of the major findings of this study. A more detailed discussion is contained in another volume of the same title ("User Benefits and Funding Strategies")* hereafter referred to as the main report.

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* J. L. Archer, C. F. Day, and N. A. Beauchamp, "User Benefits and Funding Strategies," Stanford Research Institute, SRI-H-5-283, October 1975.

II SUMMARY OF STUDY RESULTS

A. GENERAL

SRI has developed a methodology that allows determining the IUS payloads of highest importance for a given set of objectives. The methodology can be used to subject a list of candidate payloads to a rank-ordering process, or it can be used to identify the experiments and instruments appropriate for inclusion on high-importance IUS payloads. There are three major steps involved in the technique: (1) justification of the experiments that make up an IUS payload, (2) importance ranking of these experiments, and (3) payload selection.

B. JUSTIFICATION OF EXPERIMENTS*

In the first of the three steps in the methodology, experiment justification, candidate IUS experiments are subjected to three tests to determine: the relevance to accepted objectives, the sufficiency of the related benefits, and the relative worth of the experiment when compared to alternative approaches. If an experiment passes these tests, it is said to be justifiable; that is, its utility meets some minimum set of standards to merit its further consideration for inclusion on an IUS payload.

In determining the relevance of specific experiments to accepted objectives, only objectives that have generally recognized merit should be used. The Hearth Objectives serve as an initial set of such objectives that can be used in the early exercising of the methodology. These objectives (listed in Appendix B of the main report) are likely to change in time, however, and are probably not complete even in their current form; for example, little basic scientific research appears justifiable

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* A more detailed discussion is presented in Section II of the main report.

Table 1

IUS EXPERIMENTS/INSTRUMENTS CATEGORIZED BY OBJECTIVE

NO.	FAIRCHILD EXPERIMENTS/INSTRUMENTS	GLOBAL CROP PRODUCTION	WATER AVAILABILITY	LAND USE AND ENVIRONMENTAL ASSESSMENT	LIVING MARINE RESOURCE ASSESSMENT	TIMBER INVENTORY	RANGELAND ASSESSMENT	LARGE SCALE WEATHER	WEATHER MODIFICATION	CLIMATE	STRATOSPHERIC CHANGES AND EFFECTS	WATER QUALITY	GLOBAL MARINE WEATHER
1	ORBITING STANDARDS PLATFORM												
2	MILLIMETER WAVE BROADBAND EXP.												
3	MILLIMETER WAVE SATELLITE-TO-SATELLITE EXP.											1	
4	HYDROMETER ATTENUATION DEPOLARIZATION EXP.	1?	1?					1?					
5	EFI INVESTIGATION										2		
6	FIXED AND MOBILE SATELLITE COMMUNICATION		2								2	2	
7	ORBITAL ANTENNA RANGE												
8	RELAY STATION FOR DEEP SPACE PROBES												
9	ATMOSPHERIC X-RAY EMISSION DETECTOR	1	1				1	2	1	2	2		1
10	STEREO SEVERE STORM SENSING	2	2				1	3	3	2	1	1	3
11	MICROWAVE VERTICAL ATMOSPHERIC SOUNDER	2	1	2	2	2	2	3	3	3	1	1	3
12	MICROWAVE MEASUREMENT OF TEMPERATURE AND WATER VAPOR PROFILES	1	2	1	1	1	2	3	1	3	2	1	3
13	GEOSYNCHRONOUS CLOUD PHYSICS RADIOMETER	3	2		1		1	3	3	3	2	2	3
14	RADAR MEASUREMENT OF PRECIPITATION RATES OVER THE OCEAN		1		1			3	3	3	2	1	3
15	RADIO INTERFEROMETRY POSITION LOCATER												
16	CO_2 LASER SYNCHRONOUS SATELLITE DATA RELAY RECEIVER EXP.							1			1	1	
17	GEOSYNCHRONOUS LASER REFLECTOR												
18	PRECISION ATTITUDE DETERMINATION SYSTEM (PADS)												
19	PRECISE & ACCURATE TIME AND TIME INTERVAL EXP. (PATTI)												
20	FUEL CELL												
21	ECLECTIC SATELLITE PYROHELIOMETER												
22	HIGH VOLTAGE SOLAR ARRAY SPACE PLASMA DRAINAGE EXP.												
23	MERCURY ION ENGINE	2	2	2	2	2	2	2	2	2	2	2	2
24	LIQUID METAL SLIP RINGS								2				
25	CESIUM ION ENGINE	2	2	2	2	2	2	2	2	2	2	2	2
26	TEFLON ENGINE	2	2	2	2	2	2	2	2	2	2	2	2
27	COLLOID ION ENGINE	2	2	2	2	2	2	2	2	2	2	2	2
28	DATA COLLECTION SYSTEM	1	1		1	1	1	2	2	2	2	2	2
29	MILLIMETER WAVE COMMUNICATION EXP.							1			1	1	1
30	ELECTROMAGNETIC ENVIRONMENT EXP.										2		
31	MULTIBEAM EXP.		2								2	2	
32	INTEGRATED COMMUNICATION EXP.	1	2	1	1	1	2	3	2	3	2	2	3
33	1.5-M TELESCOPE RADIOMETER	3	3	3	2	[illegible]	3	3	3	2	1	3	2

KEY: 3 = STRONG RELEVANCE
2 = MODERATE RELEVANCE
1 = PARTIAL RELEVANCE

BLANK = WEAK, NONE, OR UNKNOWN RELEVANCE

(hatched cell) = STRONG TO MODERATE RELEVANCE CITED FOR HEARTH SYSTEMS

Table 1 (Continued)

NO.	LOCAL WEATHER AND SEVERE STORM	TROPOSPHERIC POLLUTANTS	HAZARD WARNINGS	COMMUNICATIONS/NAVIGATION	SOLAR POWER	POWER RELAY	HAZARDOUS WASTE DISPOSAL	WORLD GEOLOGICAL ATLAS	DOMESTIC COMMUNICATIONS	INTERCONTINENTAL COMMUNICATIONS	BASIC PHYSICS AND CHEMISTRY	MATERIAL SCIENCE	COMMERCIAL INORGANIC PROCESSING	PRODUCTION, ISOLATION OF BIOLOGICALS	COMMERCIAL PROCESSING OF BIOLOGICALS	EFFECTS OF GRAVITY ON TERRESTRIAL LIFE	MAN LIVING AND WORKING IN SPACE	PHYSIOLOGY AND DISEASE PROCESSES	DISEASE CARRYING INSECTS	EARTH'S MAGNETIC FIELD	CRUSTAL DYNAMICS	OCEAN INTERIOR AND DYNAMICS	DYNAMICS AND ENERGETICS OF THE LOWER ATMOSPHERE	STRUCTURE, CHEMISTRY, DYNAMICS OF STRATOSPHERE/MESOSPHERE	IONOSPHERE - MAGNETOSPHERE COUPLING
1	1		1	3	1?	1?			3	3													1	1	
2	2		2	3	1?				3	3													2	2	
3	1		1	2					3	3									1						
4	1		1	2					2	2	1?												1	1	
5	2			3					3	3													2	2	
6	2	2		3					3	3															
7	1		1	3	1?	1?			3	3	1												1	1	
8																									
9	1			2	1	1			1	1										2			3		3
10	3		2	2	1	1			2	2															
11	3		1	1	1	1			1	1													1	1	2
12	3	1																				2	3	2	
13	3	3	1	1																		2	3	3	
14	2		1																				2	2	
15			1	3	1	1			1	1															
16	1		1	3					3	3													1	1	
17				3		1			3	3															
18				3	3	3																			
19				3					1	1	2														
20	2		2	2	2	2			2	2			2		2		2								
21			1	2					2	2													2	2	2
22				2					2	2			2		2		2								
23	2	2	2	2		2		2	2	2								2	2			2	2	2	
24				2					2	2			2		2		2								
25	2	2	2	2		2		2	2	2								2	2			2	2	2	
26	2	2	2	2		2		2	2	2								2	2			2	2	2	
27	2	2	2	2		2		2	2	2								2	2			2	2	2	
28	3	2	3	3					3	3									2						
29	2	2	3	3					3	3													2	2	
30	2			3					3	3													2	2	
31	2	2		3					3	2															
32	3	2	3	3					3	3									2			2	3	2	
33	3	1						3	1	1									3			2	2		

KEY: 3 = STRONG RELEVANCE
2 = MODERATE RELEVANCE
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BLANK = WEAK, NONE, OR UNKNOWN RELEVANCE

▨ = STRONG TO MODERATE RELEVANCE CITED FOR HEARTH SYSTEMS

under the Hearth Objectives listed and communication R&D activities appear to be deemphasized. Thus, a monitoring activity is needed within NASA to determine the timeliness and completeness of the objectives used.

The determination of relevance of the IUS experiments (primarily in the R&D stage) to accepted objectives could be made without reference to well defined, non-redundant operational systems:* one could assign a high relevance rating to a candidate experiment if it has the potential of making large contributions in support of a given objective, regardless of whether the system, whose development is supported by the experiment, is being seriously considered for implementation or not. The numerical entries in Table 1 were derived in this way. However, the significance of the results of the relevance test is somewhat vague if this approach is used, and the benefit sufficiency test that follows the relevance test is not real'v well defined until one specifies the services provided by the operational system. Therefore, the appropriate relevance entries are those derived in the context of a specific set of operational systems. The systems identified by the Hearth Committee form a set of non-redundant operational systems supporting the Hearth Objectives. However, the set of experiments/instruments examined by Fairchild does not correspond very well to the list of instruments identified by the Hearth Committee as requiring additional R&D to field the Hearth operational systems. Some correlation does exist as indicated in Table 1 where a shaded box represents possible utilization of a Fairchild instrument in the operational system proposed by the Hearth Committee for meeting a specific Hearth Objective. The lack of complete correlation, however, means that determination of a full set of appropriate relevance entries is not possible at this time. Therefore, the subsequent analyses performed for the Fairchild instruments serve primarily to illustrate the use of the

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* An operational system is a non-R&D system which is an integral and contributing element in the overall structure set up to perform the day-to-day operations of a user agency. For example, to COMSAT, an operational system is one that can be relied upon to transmit messages or data in response to the demands of COMSAT's customers. Such a system does not merely provide a demonstration of technology for use in an advanced system.

methodology and the derived importance rankings must be viewed as preliminary until more complete, consistent, and well defined sets of experiments/instruments and operational systems are available.

The second test in the experiment justification step of the methodology is that of determining the sufficiency of benefits arising from the candidate experiment. This test is initially made by comparing the life-cycle costs of the operational system(s) with the benefits that accrue from implementing the system(s), the development of which is supported by the experiment under consideration. If these costs are less than the benefits, the experiment passes the test. If the costs exceed the benefits, then it must be determined if some other benefit (for example, the benefit from basic science experiments) warrants continued consideration of the experiment. In utilizing the results of existing benefit analyses, it was determined that only a few IUS experiments may pass this benefit test without ambiguity. This is due to uncertainties* in two factors which markedly influence the level of benefits obtainable from implementing a given system: (1) the uncertainty of the extent to which the services provided will actually be utilized by the potential users and (2) the uncertainty of the benefits from a specified level of utilization of the service.

The third and last test in the experiment justification procedure is to determine if, among the alternative approaches to develop the capability to field worthwhile operational systems, the candidate IUS experiment offers the best approach. Early in a development program, the answer to this question may not be known. In this case, competing approaches (experiments) should be retained as justifiable experiments. As soon as the query can be answered without ambiguity, however, the less desirable approaches should be dropped or, at least, assigned a low importance ranking. This tradeoff analysis is one of the most critical operations

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* As a result of these uncertainties, the hard, demonstrable cost benefits may be only a fraction of the potential cost benefits that could accrue from an operational system.

in the entire methodology.* It was used to identify possibly redundant candidate experiments that could be eliminated from further consideration.

C. RANKING OF JUSTIFIED EXPERIMENTS**

Following the first step, instrument justification, the methodology then calls for ranking the justified instruments in order of importance. A set of criteria has been identified to effect this ranking. These criteria are: the level of benefits; the number of application (objective) areas benefited; the importance of the objectives supported by the experiment; the criticality of the experiment to the implementation of the pertinent operational system(s); timeliness of the experiment; and special-case criteria such as previous commitments, legislative action, and national prestige.

A technique was developed whereby a quantitative importance level could be assigned to each candidate IUS experiment, consistent with the above criteria. The method consists of: (1) determining "partial importances" related to the level of cost benefits, the timeliness, and the criticality of the experiment, as well as the importance of each relevant objective; (2) multiplying these partial importances together for a given objective; and (3) then, summing over all objectives benefited by the experiment. Table 2 shows the results of applying the method to the Fairchild set of experiments/instruments using the entries in Table 1 as a measure of the criticality of each experiment. The resulting importance ratings should be viewed with the following caveats, however:

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* In fact, unless similar tradeoff analyses are made at the operational system level, the analysis for IUS experiments could be somewhat academic. That is, the operational systems used in the IUS analysis should first have been shown to represent reasonable, if not the best, operational systems for supporting the objectives. In particular, the operational space-based systems should have been shown to offer advantages over ground-based or aircraft-based systems.

** A more detailed discussion is in Section III of the main report.

Table 2

RELATIVE IMPORTANCE RANKING RESULTING FROM SAMPLE RATING METHOD

Importance Level	Fairchild Experiment/Instrument	Importance Rating	Normalized Rating
High	1.5-m Telescope Radiometer	10.8	1.0
	Integrated Communication Experiment	10.7	0.99
	Ion Engine	10.3	0.95
	Microwave Vertical Atmospheric Sounder	10.3	0.95
	Microwave Measurement of Temperature and Water Vapor Profiles	9.5††	0.88††
	Geosynchronous Cloud Physics Radiometer	9.0	0.83
	Data Collection System	8.8	0.82
Moderately High	Stereo Severe Storm Sensing	7.5	0.70
Moderate	Millimeter Wave Communication Experiment	5.8††	0.54††
	Atmospheric X-Ray Emission Detector	5.5	0.51
	Fixed and Mobile Satellite Communication	5.3	0.49
	Multibeam Experiment	5.3	0.49
	Millimeter Wave Broadband Experiment	4.8	0.44
	Fuel Cell	4.7	0.44
	EM Environment Experiment RFI Investigation } *	4.7††	0.44††
	Radar Measurement of Precipitation Rates Over the Ocean	4.7	0.44
	CO_2 Laser Data Relay Experiment	4.7	0.44
Moderately Low	Orbital Antenna Range	4.3	0.40
	Orbiting Standards Platform	4.3††	0.40††
	Hydrometer Attenuation/Depolarization Experiment	3.8	0.35
	Millimeter Wave Satellite-to-Satellite Experiment	3.8	0.35
	Liquid Metal Slip Rings	3.3	0.31
	Geosynchronous Laser Reflector	3.2	0.30
	Eclectic Satellite Pyroheliometer	3.2	0.30
	High Voltage Solar Array Experiment	3.0	0.28
Low	Radar Interferometry Locater	2.2	0.20
	PADS **	2.0	0.18
	PATTI **	2.0	0.18
	Relay Station for Deep Space Probes†	0.0	0

* As discussed in main report, apparently only one of these is needed.

** Low rankings for PADS and PATTI due to lack of explicit identification of areas of application in Table 1. Additional information could markedly change the rankings assigned.

† Inclusion in list not justified on basis of Hearth Objective.

†† Inclusion of these experiments in the Integrated Communication Experiment implies that these nominal ratings should actually be set equal to zero.

(1) The level-of-benefits "partial importance" parameter was set equal to unity for all experiments. It was not possible to calculate the parameter for each experiment because the operational systems for the list of instruments have not been adequately defined. Therefore, neither the hard benefits nor the total system costs were available to compute the parameter. The cost benefit analyses for selected Hearth systems in Section II-B.3.d of the main report, however, show that values of less than 0.5 can be anticipated for the level-of-benefits factor. Thus, subsequent analysis with more complete data will reduce the importance ratings of many of the experiments listed in Table 2.

(2) The ratings in Table 2 were derived using the relevance (criticality) factors shown in Table 1. The entries in Table 1, however, must be considered preliminary until the operational systems corresponding to the experiments/instruments are well defined. When these operational systems are defined, a new table can be constructed which will reflect realistic estimates of the experiment/instrument criticality. Some new entries will be added, and the criticality ratings of existing entries will probably be modified either upward or downward. For example, PATTI and PADS may have much higher importance levels than shown in Table 2, when subjected to the importance rating exercise using the complete input data, because of their intended use in operational systems to provide accurate pointing and precise time control capabilities that are critical to optimization of these operational systems.

(3) The timeliness factor used in this rating exercise was also set equal to unity in deriving the ratings shown in Table 2 because the operational systems and their implementation schedules were not defined. However, more appropriate values can be determined when valid data are available. For example, depending upon the operational systems' deployment schedule, the Ion Engine may not be required before the middle 1990's when the number of communication satellites and their users becomes so large as to require a very accurate station-keeping capability. Thus, a value of 0.5 for the timeliness may be appropriate for this experiment/instrument in its application to communications. Similar observations apply to the use of this instrument for Power Relay (the capability will probably not be needed until many years after IUS flights). Consequently, reducing the timeliness factor to its more realistic value of 0.5 for the related Hearth Objectives for these example

cases would reduce the normalized importance rating from 0.95 to 0.85, which is still, however, within the High Importance Level category.

(4) None of the Special Criteria were applied in determining the importance ratings in Table 2 and only the Hearth Objectives identified in Appendix B of the main report were used to define the application areas considered. Consequently, although the Relay Station for Deep Space Probes was assigned an importance rating of 0.0, it will have a higher rating if a space science objective is added to the existing Hearth Objectives, or if NASA has committed this instrument to an approved deep space mission.

Although the rankings shown in Table 2 should be considered preliminary, the paradigm developed in the study has been shown to be feasible in application and to yield appropriate importance rankings based on the preliminary input data available and the criteria identified. A conclusive rank-ordering, however, will depend upon provision of accurate and complete input data.

D. PAYLOAD SELECTION*

The third and final step of the methodology consists of formally selecting high-priority IUS payloads. The following set of eight criteria was developed and illustratively exercised to rank-order previously defined payloads and to select the experiments for a high-priority payload:

(1) Technical Compatibility: The payload must observe the weight, volume, and power constraints of the spacecraft.

(2) Non-Duplication: Experiments should not be duplicated needlessly on an IUS flight.

(3) Experiment Importance: Preference should be given to experiments rated high in importance in the second step of the methodology (see Section C).

(4) Experiment Completeness: If a decision is made to fly an experiment critically needed for an operational system, all experiments needed for that system should be scheduled for flight, either on IUS or on other systems, to assure execution of all required R&D activities for the operational system.

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* A more detailed discussion is in Section III of the main report.

(5) Sponsorship: Preference should be given to experiments for which non-NASA funding sources are most probable.

(6) Time Phasing: One should time-phase those experiments to be sponsored by a given sponsor to match his budgetary constraints.

(7) Immediacy: Preference in IUS payloads should be given to experiments that support rapid deployment of operational systems.

(8) Spacecraft Utility: Every attempt should be made to make full utilization of the spacecraft capacity on each flight.

A quantitative measure of importance for IUS payloads has been defined by SRI, consistent with the above eight criteria. This measure has been used to rank order selected IUS payloads proposed by Fairchild.

The payload importance function was used to construct a method for selecting IUS payloads in decreasing order of importance where each payload selected is the most important of all possible IUS payloads for a specified spacecraft capability and list of candidate experiments, given the selection of the previous more important payloads. The selection process reduces to a problem in non-linear programming where each experiment has associated with it a variable that takes on the value 0 or 1, depending upon whether that experiment is present or absent from the payload. An algorithm exists to perform this selection process without having to examine all possible payloads.

E. FUNDING STRATEGIES*

Various cost-sharing strategies were assessed for IUS missions. These included: long-run marginal cost, long-run costs, short-run marginal cost, average (full) cost, two-part pricing, and value-of-service strategies. Each strategy was rated against five criteria: efficiency, equity, sponsor's ability to pay, recovery of costs, and administrative

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* A more detailed discussion is in Section V of the main report.

ease. No one strategy was found to offer a clear-cut advantage over the others for all potential sponsors. Thus, in view of the fact that the best strategy may vary from one sponsor to another, it is suggested that NASA maintain a flexible strategy within the constraints imposed by Congress or other agencies of the government.

The SRI analysis defined the elements of cost to be developed and ways for assigning common costs. The results provide a basis for using the following allocation strategies:

(1) Long-run costs - It will be valuable to develop long-run incremental costs as a yardstick for comparison even if no costs are actually allocated on this basis, because these costs can be used as a proxy for long-run marginal costs, the most efficient strategy available (in terms of resource allocation). It should be noted that long-run marginal costs will approximate those for the short run if Shuttle R&D costs are excluded and there is only a small impact from the under- or over-utilization of existing capacities.

(2) Short-run marginal costs - These costs are readily estimated on an incremental basis and should be the basis for charges to other government agencies. Short-run marginal costs reflect the utilization of resources actually required to achieve the marginal launch.

(3) Two-part pricing - Two-part pricing strategies may be appropriate as a basis for charges to non-government users. These have the effect of higher than marginal costs for the first units of service with additional units priced at the margin.

(4) Average cost pricing - Average cost pricing has the advantage of recovering all costs associated with a particular activity. It may be advantageous to use average cost methods in a two-part pricing scheme.

Particular advantages were found for using a short-run marginal cost approach for other government agencies and for two-part pricing strategies for non-government users. However, in many (if not most) cases, no strategy will either enhance NASA's ability to attract early participation or encourage the marginal (next) mission. In addition, it was recognized that formal attempts to implement cost-sharing strategies may actually

inhibit the realization of potential benefits from an operational system by unfavorably influencing a potential user on his decision to use the service. Thus, while participation by other government agencies may be appropriate, attempts to charge ultimate users for service may be partially self defeating.

III CONCLUSIONS AND RECOMMENDATIONS

The major conclusions to be drawn from the SRI study are as follows:

(1) An adequate methodology for selecting justified, high-priority IUS payloads has been developed. However, the users of the methodology should recognize that:

(a) Objectives must be continually monitored and updated, as needed, to assure current political, social, and technical acceptability.

(b) Justification of many experiments may have to be made on the basis of potential, rather than hard, demonstrable, cost benefits or on bases other than cost benefits.

(c) The high importance assigned to the IUS instruments and payloads selected by the methodology is dependent upon identifying operational systems that have, themselves, been shown to be the "best" among alternatives.

(d) Although techniques have been developed (i) to rank order candidate IUS experiments/instruments and previously defined IUS payloads and (ii) to identify the most important IUS payloads in order of decreasing importance, each represents only one possible method (albeit a reasonable one) whereby one can systematically assign a quantitative value to the "importance" of an experiment or payload.

(2) NASA should maintain flexibility in its funding strategies because of differences among potential sponsors and because of possible changes in governmental policy related to setting user charges. Charging policies appropriate for governmental and non-governmental sponsors were identified.

In view of the above observations, SRI recommends that the following steps be taken:

(1) A compatible set of experiments and operational systems should be identified.

(2) The Hearth Objectives should be expanded to include space and basic science objectives, if this has not already been done.

(3) The various costs associated with the candidate payloads and experiments should be identified to provide the data base needed for NASA to determine the actual costs for a flexible pricing strategy. These data are needed because many potential sponsors are on four-year or longer budget cycles, and rather firm pricing data are needed quickly to enhance the possibilities of enlisting these sponsors for IUS flights.